The Effects of Displaying the Time Targets of the Manchester Triage System to Emergency Department Personnel: A Prospective Cross-Over Study

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Abstract

Background: The use of triage systems such as the Manchester Triage System is a standard procedure to determine the sequence of treatment in emergency departments. When using the Manchester Triage System, time targets for treatment are determined. These are commonly displayed in the emergency department information system to emergency department staff. Using measurements as targets has been associated with a decline in meeting those targets.

Objective: We investigated the impact of displaying time targets for treatment to physicians on processing times.

Methods: We analyzed the effects of displaying time targets to emergency department staff on waiting times in a prospective cross-over study during the introduction of a new emergency department information system. The old information system version used a module that showed the time target determined by the Manchester Triage System, while the new system version used a priority list instead.

Results: The average emergency department length of stay and waiting times increased when using an emergency department information system that did not display time targets (time from admission to treatment t ?pre = 15 min., IQR = 6-39, t ?post = 11 min., IQR = 5-23). However, severe cases with high acuity (as indicated by the triage score) benefited from lower waiting times (0.15 times as high as in pre-intervention for MTS1, only 0.49 as high for MTS2). Furthermore, patients with severe injuries were less likely to receive delayed treatment, and we observed reduced odds of late treatment when crowding occurred.

Conclusions: Our results suggest that it is beneficial to use a priority list instead of displaying time targets to emergency department personnel. Time targets may lead to false incentives. Our work highlights that working better is not the same as working faster.

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Keywords: EHR, Emergency Medicine, AKTIN, Process Management, Crowding

Introduction

The use of triage systems, such as the Manchester Triage System (MTS) and the Emergency Severity Index (ESI), is a standard procedure to determine the sequence of treatment in emergency departments (EDs) [1–4]. The MTS and ESI are used for determining time targets for physician contact. These time targets are usually displayed to ED staff by the emergency department information system (EDIS). However, it is not known how this affects ED processing times. This study investigates the impact of displaying these time targets for treatment to physicians within the emergency department on processing times.

Such sociotechnical systems directly impact healthcare delivery. The data they produce can be used to improve efficiency and effectiveness in a learning healthcare system [5]. Efficient treatment is necessary because EDs around the world are experiencing an increase in the number of patients they have to treat. Therefore, EDs must determine who to treat to avoid negative outcomes due to inadequate inpatient capacity. *Crowding* is an everyday challenge for EDs that is commonly quantified by extreme patient occupancy (*patients present* in the ED), extended *length of stay* (LOS) in the ED, and *waiting time* between triage and treatment [6, 7]. Crowding occurs if the demand for

emergency care surpasses the available resources within the ED [7, 8]. Triage systems are thus necessary to manage the treatment sequence and optimize patient flow [1–4].

These systems are used to quickly assign patients arriving at the ED a triage score, which defines the priority of treatment. The scores are mostly based on the acuity of the patient's illness and aim at identifying the risk of negative patient outcomes and ensuring timely and adequate treatment [3]. It is mandatory for German EDs to put patients through a triage process or treat them directly. The majority of EDs in Germany use 5-tier triage systems, the most commonly used being the Manchester Triage System (MTS) and the Emergency Severity Index (ESI) [1]. Using these, the acuity of all patients is categorized through a 5-tiered scale resulting in 5 levels of urgency typically known to personnel by the associated color (c.f. Table 1).

With the MTS, a time target is determined by a certified nurse with flowchart diagrams. This target is the latest time that is acceptable until a physician consults the patient. In Germany, these times are between 0 (Level 1, MTS1) and 120 minutes (Level 5, MTS5), contrary to the international version, which sets a limit of 240 minutes (Level 5, MTS5) [1, 9]. For example, a patient with an MTS score of MTS2 should be attended by a physician within ten minutes in Germany. A re-triage is possible at any time; however, it becomes mandatory if the proposed time target is not reached.

Table 1: Definition of the Manchester Triage System.

Level	Triage Score	Color	Acuity	Time target
1	MTS1	Red	Immediate	0 min.
2	MTS2	Orange	Very urgent	10 min.
3	MTS3	Yellow	Urgent	30 min.
4	MTS4	Green	Standard	90 min.
5	MTS5	Blue	Non-urgent	120 min.

The triage process and subsequent treatment are usually implemented within the EDIS, supporting clinical documentation, patient tracking, and order management. The triage system and the implementation of the triage system in the EDIS thus represent potential target areas for reducing waiting times and improving patient flow and, as a result, ED efficiency [10, 11].

The triage system and its implementation in the EDIS directly impact the provision of care, waiting times, LOS, and overall patient flow (c.f. Figure 2) [1, 9–12]. Formally structured and established triage systems have higher validity than informally structured systems, but overall performance varies considerably [13, 14]. Using a Dutch version of the MTS in a before-and-after study, Storm-Versloot et al. [15] could not see any effects of triaging patients on waiting times, but in fact observed increased average waiting times (Δt = 15min) and increased average treatment times (Δt = 14min). However, urgent cases (Level 2) received treatment faster on average (Δt = 4min), and patient satisfaction with respect to waiting times was higher, especially among low urgency patients who typically crowd the ED. Using computational experiments, van Bockstal et al. [16] similarly associated triage with increased waiting times for patients with less severe injuries and decreased waiting times for acute patients. They also found that there was a beneficial effect on triage system resource consumption. Vegting et al. [17], on the other hand, reported a general increase in LOS of non-critically ill patients due to triage, attributing it to the fragmentation of the provision of care. However, triage and waiting times are not only important quality management factors but also significantly impact patient satisfaction. Multiple studies suggest that patients care a lot about the time they spend in the ED and receiving information on the length of their projected waiting time, which demonstrates that patient satisfaction correlates strongly with waiting time [18, 19]. Aside from these observational studies, ED routine records have been used to predict waiting times using, e.g., machine learning [20] and statistical approaches [21, 22].

The time it takes to receive treatment is thus understood to be a crucial metric for assessing quality within the ED. Policy-makers have also recognized the importance of ED waiting times, but some of the approaches taken to improve these are controversial. In the UK, for example, the waiting time target that has been set for EDs is four hours [23]. It is well known that using measurements as targets is associated with a decline in meeting those targets [24]. This association, known as Goodhart's Law [25] and originating from economics, has often been discussed in the context of healthcare systems, with some experts believing that setting time targets leads to false incentives within the healthcare systems [26, 24, 20].

Aside from such legislative requirements, time targets have clinical relevance in managing incoming patient flow within the ED. To track waiting patients, EDIS that implement the MTS usually display the time target determined by the triage score. Such sensory cues add to the cognitive load of attending personnel [27, 28]. Further, time pressure may have negative effects on physicians' performance [29, 30].

Therefore, the objective of this study was to analyze the effect on waiting times of displaying treatment time targets provided by the MTS score in the EDIS.

We hypothesized that displaying these targets can alter treatment and waiting times, thus influencing patient flow and crowding. We expected, in accordance with Goodhart's law, that the practice of displaying time targets for patient treatment, inadvertently contributes to inefficient patient management within emergency departments. We proposed that the display of these time targets creates a false incentive structure for ED physician personnel. It potentially leads them to prioritize meeting these targets over other critical aspects of patient care. This focus on time targets might result in suboptimal treatment decisions, potentially exacerbating patient wait times and lowering throughput, contrary to the intended purpose of these targets.

Methods

Based on routine documentation, we conducted a prospective cross-over study of all adult patients treated before (*pre-intervention*) and after (*post-intervention*) an update of the EDIS module used in the ED. The new version no longer displayed MTS time targets but a priority list (c.f. Figure 1). Subjects thus received treatment with and without displaying treatment time targets provided by the MTS score. The study was approved by an ethics committee before the update of the EDIS module (Medical Ethical Committee Uni Oldenburg, Vote-No: 2016-05, Chair F. Griesinger). Results are reported according to the STROBE guidelines [31].
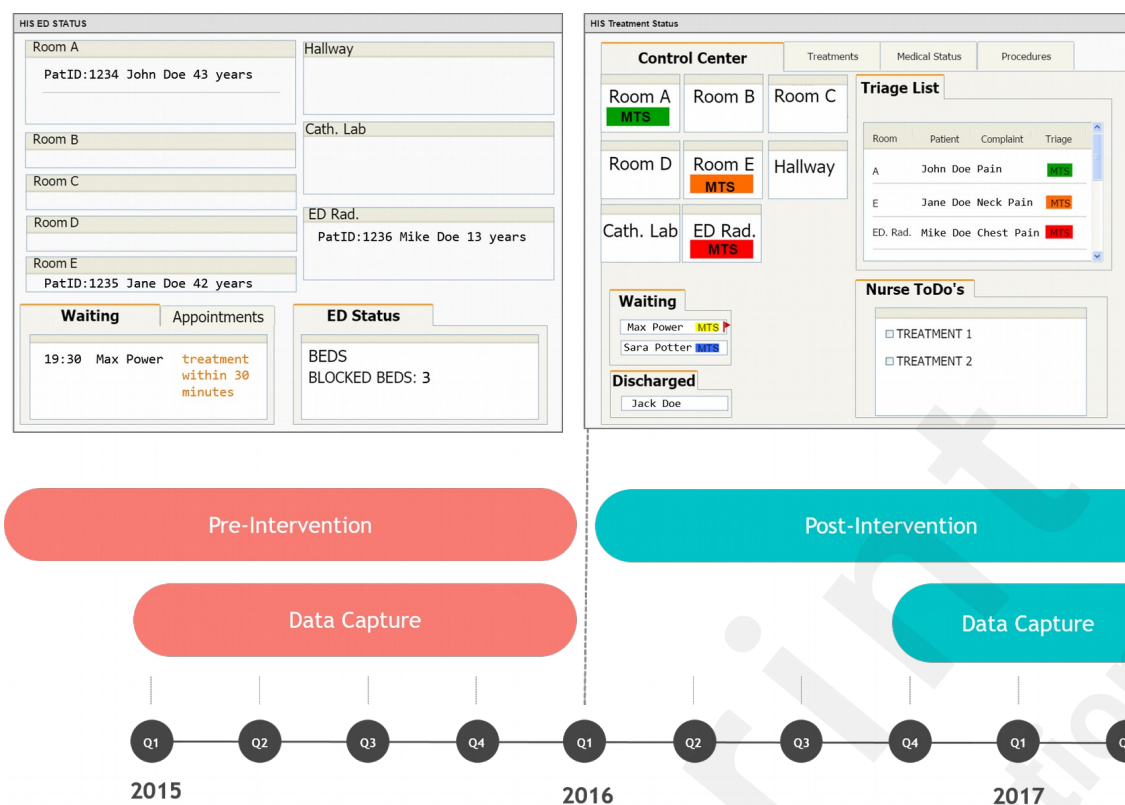
Figure 1: Study design and mock-ups of the emergency department information system (EDIS). In a prospective cross-over study, we evaluated the effect of displaying treatment time targets provided by the Manchester Triage System score to emergency department personnel. Pre-intervention and post-intervention took place before and after the update of an EDIS. The EDIS showed the time target determined by the Manchester Triage System (MTS) pre-intervention (TRIAGE TIME in mock-up). Post-intervention, a priority list (Triage List in mock-up) was displayed instead of a time target. A red flag was displayed next to the color-coded MTS score when the time target was reached.

Study Context

We conducted the study within the ED of the Klinikum Wolfsburg in Germany, a central public hospital with around 70,000 patients per year. It is the only hospital to have an ED within a 17 km radius. It has a certified trauma center and processes 35,000 patients in the ED every year.

The standard procedure for patients arriving at the ED (in both phases) involved administrative registration, followed by a triage conducted by a nurse, re-triage if necessary, treatment by a physician following a certain waiting time, and finally discharge. In urgent cases (e.g., admission by ambulance), triage is bypassed if there are sufficient resources.

No additional training on triage practices was conducted during the study period, and staff received solely technical training from the software vendor before the implementation of the new module. The staffing levels, both for nursing and medical personnel, remained unchanged throughout the study. The medical staffing in the emergency department adhered to a fixed schedule, with specific shifts throughout the day and night, maintaining a team of 13.7 full-time equivalent positions for physicians directly associated with the emergency department and 29.2 full-time equivalent positions for nursing staff. This staffing model was consistently applied, without differentiation between weekdays, weekends, or public holidays. There were no notable changes in equipment during the study.

The EDIS used in the ED is a module of the monolithic hospital information system ORIBS (Dedalus Healthcare, Germany). The EDIS documentation method adhered to the emergency department medical record of the German Interdisciplinary Association for Intensive Care and Emergency Medicine (DIVI e.V.). The captured routine documentation data is accessible through the AKTIN Emergency Department Data Registry. [32, 33].

Study Design

During the pre-intervention phase (01/01/2014 to 12/31/2014), nurses carried out triage and documentation anonymously using paper-based MTS presentation flowcharts and documented data in a view only accessible to the nurses. Nursing care was documented externally. Time points of patient contact and triage score were displayed to physicians and nurses in a user interface (UI) developed in-house. The UI used consisted of a list-based view of rooms and patients. Triage and time targets were visible to all personnel in a room overview. Patients were selected for treatment according to the displayed list. Physicians could open an emergency department medical record by clicking on triaged patients.

Post-intervention (10/13/2015 to 01/31/2016), the Cockpit Notaufnahme EDIS module provided by Dedalus Healthcare was used, which no longer displayed the MTS time target.

Post-intervention, data were collected after a *transition period* between the intervention phases to mitigate potential biases (c.f. Figure 1). During this interval, the adaptations to the new intervention were allowed to stabilize. Apart from using electronic rather than paper flowcharts for determining the MTS, the changes were purely cosmetic. Standard procedures for incoming patients remained the same. The new user interface displayed patients to nurses and physicians in a list according to the urgency of treatment without time targets. A room-based overview of patients was included in the new UI, which served as an overview for all personnel. Patients could be selected and assigned to rooms through drag-and-drop. A signal was displayed when time targets were exceeded.
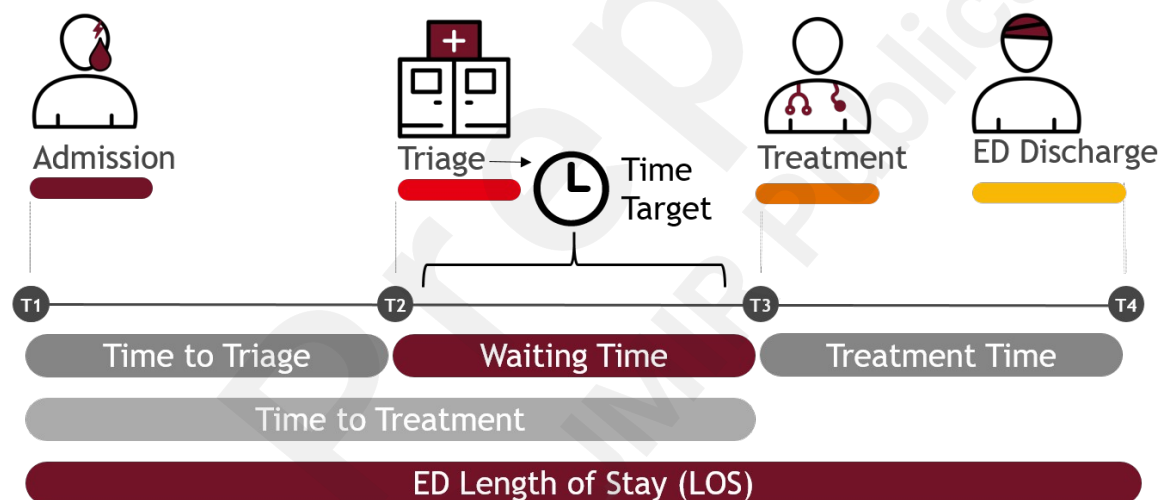

Figure 1: Data collection and variable definition. The evaluation of the intervention was based on routine documentation stemming from an emergency department information system. Timestamps describing internal patient flow were derived from routine medical records. The main target parameters were time to triage (first contact with a triaging nurse), waiting time from triage until treatment by the physician (first contact with the attending physician), and ED length of stay.

Data acquisition

We extracted process times at the end of the post-intervention phase Data was collected routinely by the EDIS, anonymized within the clinic, and provided through the infrastructure of the AKTIN Emergency Department Data Registry [32, 33].

The main target parameters were the time until triage, waiting time from triage until treatment by the physician, and ED length of stay (c.f. Figure 2). As a secondary outcome, we calculated a binary classification of late treatment as defined by the assigned triage score, which we interpreted as a

proxy for ED efficiency (e.g., "1" if waiting time was longer than ten minutes for patients assigned the triage score MTS2).

Data Exclusion

Documentation errors may lead to implausible or missing timestamps. We considered a physician contact before initial assessment non-evaluable and excluded non-positive processing times as well as data with missing admission or triage timestamps. We classified length of stay and waiting time that lie above three standard deviations ($>3\sigma$) from the mean (μ) of patients with the lowest acuity (MTS5), rounded to the next complete hour, as outliers. Any processing time between admission, triage, and treatment above 300 minutes or a LOS higher than 600 minutes thus resulted in exclusion. Further, we omitted data from the transition period.

Data analysis

Timestamps were generated automatically by the EDIS when a nurse registered a patient, when a nurse opened the triage view and documented the *triage score,* when the physician opened the ED record, and when the patient was marked as discharged by the physician (c.f. Figure 2). We deduced direct physician contact from the occurrence of missing triage timestamps in combination with physician contact timestamps. In addition, we included data on the count of *patients present at the time of physician contact* (T3, c.f. Figure 2) using a counter that we set to "1" for the first patient in the dataset. From the admission timestamp, we extracted *the annual season*, *hour of the day*, and whether the admission occurred on a *working day* (as opposed to a non-working day). We corrected erroneous data with the clinic's help and excluded implausible timestamps (i.e., timestamp treatment before timestamp administration, LOS > 600 minutes) from further analysis. We performed all calculations using the statistical software R 3.6.1.

Primary analysis

We extracted the entries from the EDIS to a standardized data entry form. The descriptive main analysis included the median and interquartile range (IQR) for metric variables and the computation of absolute and relative frequencies for categorical variables. At the end of the intervention phase, we sought evaluative feedback regarding the intervention's impact and effectiveness from the head of the emergency department and ED personnel.

Secondary analysis

The secondary analysis consisted of generalized additive regression models. Response variables were waiting time until treatment in minutes and the binary occurrence of delayed treatment. The preselected set of covariates were the number of patients present within the ED at the time of physician contact MTS score, study phase, working day, annual season, and hour of day. We assumed a gamma distribution with a log-link for positive waiting times (model 1) and used logistic regression for delayed treatment (model 2). The covariate hour of the day was included with a cyclic P-spline basis. The number of patients within the ED was modeled with a regular P-spline basis and two-way interactions of MTS score and study phase, as well as patients present and study phase. The effects on waiting time are reported as multiplicative effects exp(\beta) with 95% confidence intervals. The logistic regression results are reported as odds ratios (OR), with 95% confidence intervals. The non-linear effects estimated by splines are reported graphically.

Results

In total, we extracted 48,822 datasets from the EDIS; 35,167 in pre-intervention, and 10,655 in post-

intervention. Excluding 636 datasets with implausible timestamps from further analysis, we analyzed 45,186 datasets (c.f. Supplementary Figure 1). In general, the distribution of assigned triage scores differed between pre-intervention and post-intervention (c.f. Table 2). We noticed an *upcoding* post-intervention, an increase in the assignment of more urgent triage levels. However, most triaged patients were still assigned an MTS3 or MTS4 score in both phases. Very few patients in post-intervention and none in pre-intervention were given the most urgent MTS score of MTS1. Thus, in the analyses, we focussed on patients assigned a triage score of MTS 2-5.

Table 2. Comparative analysis of pre-intervention and post-intervention study sample characteristics. Categorical variables are presented as frequencies (percentages) and were analyzed using Chi-square tests. Continuous variables are presented as means with standard deviations and reported along with their median, ranges, and quartiles. We assumed the number of patients present per day and at physician contact to be normally distributed and compared them using independent sample t-tests. Non-normal distributed waiting times were compared using Mann-Whitney U tests.

	Pre-intervention (N=34727)	Post-intervention (N=10459)	Total (N=45186)	P value
Year				< .001
2014	34727 (100.0%)	0 (0.0%)	34727 (76.9%)	
2015	0 (0.0%)	7556 (72.2%)	7556 (16.7%)	
2016	0 (0.0%)	2903 (27.8%)	2903 (6.4%)	
Weekday				.894
Working day	23399 (67.4%)	7040 (67.3%)	30439 (67.4%)	
Non-working day	11328 (32.6%)	3419 (32.7%)	14747 (32.6%)	
Season of the year				< .001
Fall	8698 (25.0%)	4527 (43.3%)	13225 (29.3%)	
Spring	8872 (25.5%)	0 (0.0%)	8872 (19.6%)	
Summer	9003 (25.9%)	0 (0.0%)	9003 (19.9%)	
Winter	8154 (23.5%)	5932 (56.7%)	14086 (31.2%)	
MTS score				< .001
LWBS	0 (0.0%)	38 (0.4%)	38 (0.1%)	
MTS1	0 (0.0%)	15 (0.1%)	15 (0.0%)	
MTS2	220 (0.6%)	186 (1.8%)	406 (0.9%)	
MTS3	4369 (12.6%)	2004 (19.2%)	6373 (14.1%)	
MTS4	10828 (31.2%)	5049 (48.3%)	15877 (35.1%)	
MTS5	3059 (8.8%)	589 (5.6%)	3648 (8.1%)	
Direct contact	16251 (46.8%)	2578 (24.6%)	18829 (41.7%)	
Adherence to MTS time target				< .001
On-time	13381 (72.4%)	5190 (68.6%)	18571 (71.3%)	
Late	5094 (27.6%)	2376 (31.4%)	7470 (28.7%)	
Patients per day				.155
N-Miss	0	0	0	
Mean (SD)	95.142 (10.618)	93.384 (13.732)	94.730 (11.435)	
Median (Range)	95.000 (64.000,	93.000 (1.000, 117.000)	95.000 (1.000,	

	127.000)		127.000)	
Q1, Q3	88.000, 102.000	86.000, 102.000	88.000, 102.000	
Patients present at Physician Contact				< .001
N-Miss	0	0	0	
Mean (SD)	12.479 (5.908)	15.108 (6.938)	13.073 (6.253)	
Median (Range)	12.000 (0.000, 33.000)	15.000 (1.000, 41.000)	13.000 (0.000, 41.000)	
Q1, Q3	8.000, 16.000	10.000, 20.000	8.000, 17.000	
Waiting time in minutes				< .001
N-Miss	16252	2893	19145	
Mean (SD)	55.831 (52.088)	58.898 (54.944)	56.722 (52.951)	
Median (Range)	39.000 (0.000, 294.000)	41.000 (0.000, 291.000)	39.000 (0.000, 294.000)	
Q1, Q3	17.000, 80.000	17.000, 85.000	17.000, 81.000	

Primary analysis

Depending on the severity of the injury, it took different times until a nurse assigned a patient a triage score. The less serious the complaint, the greater the MTS score and the longer it took until the triage score was assessed. Post-intervention, patients with an MTS3 and MTS4 were triaged slightly faster than in pre-intervention; those with an MTS5 were triaged slower (c.f. Supplementary Tables 1-5).

The percentage of patients who received immediate treatment by a physician instead of first being triaged was higher in pre-intervention (46.8%) than in post-intervention (24.6%). Incoming patients that a physician attended to immediately received treatment faster in post-intervention (time from admission to treatment t_{pre} = 15 min., IQR = 6-39, t_{post} = 11 min., IQR = 5-23). In post-intervention only, a small group of patients (n = 38) left the ED after triage but before seeing a physician. Generally, we found that the time from patient registration until triage was slightly reduced post-intervention, although still somewhat comparable.

The presence of patients had a greater impact, leading to increased waiting times at the triage stage, especially for low-urgency patients. In pre-intervention, there was a rise in the time needed until triage when more than 30 patients were present within the ED. However, we saw no such effect post-intervention. Daily patient numbers were comparable pre and post-intervention.
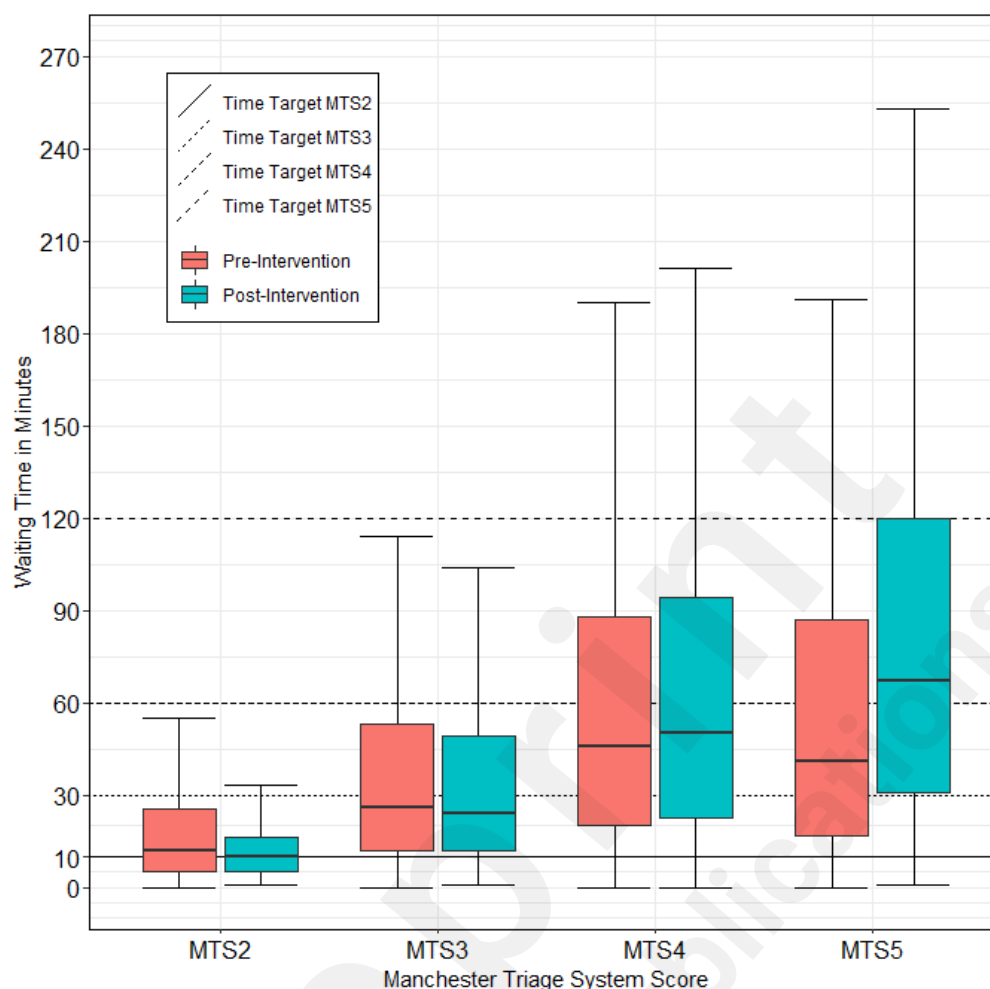
Figure 3: Waiting times from triage to treatment by assigned triage score and study phase. The old EDIS version (pre-intervention, green) displayed the time target determined by the Manchester Triage System (MTS), while the new EDIS version (post-intervention, red) did not. The waiting times from triage until physician contact varied for MTS5 (Pre: 41 min, IQR 17-87; Post: 67 min, IQR 31-121 min), MTS4 (Pre: 46 min, IQR 20-88; Post: 50 min, IQR: 23-95 min), MTS3 (Pre: 26 min, IQR 12-53; Post: 24 min, IQR 11-49 min), MTS2 (Pre: 12 min, IQR 5-26 min; Post: 10 min, IQR 5-16 min) and MTS1(Post: 4 min, IQR 2-14 min).

Crowding, as measured in patients present, was higher in post-intervention than in pre-intervention ($\dot{n}$pre = 12, IQR = 8-16, $\dot{n}$post = 15, IQR = 10-20). Accordingly, we observed an increased length of stay post-intervention. On average, patients stayed 29 min. longer in the ED ($\dot{t}$pre = 119 min., IQR = 66-189, $\dot{t}$post = 148 min., IQR = 88-226). Less severe cases with MTS4 and MTS5 – the majority of cases – waited longer (c.f. Supplementary Tables 1-5).

The waiting time from triage until physician contact increased as well ($\dot{t}$pre = 39 min., IQR = 17-80, $\dot{t}$post = 41 min., IQR = 17-85), and the time target provided by the MTS was missed in a greater percentage of triaged cases post-intervention ($\Delta n_{\square} = ¿$ 3,8 %). The rate of timely treatment changed in the same fashion. Delayed treatment and re-triage were more common in post-intervention than in pre-intervention. This effect was mainly due to cases of patients with triage scores of MTS4 and MTS5. For severely injured patients with MTS2 and MTS3, we observed a lower number of treatment instances occurring outside of the target scope. However, although these process times and statistics suggest impeded throughput, practicing physicians reported improved patient flow. Furthermore, the head of the ED reported perceiving an improvement in patient flow and treatment quality.

Secondary analysis

In the secondary analysis of positive waiting times (model 1, c.f. Supplementary Table 6), we found that waiting times increased on average by a factor of 1.27 (CI) post-intervention. ED crowding amplified this effect. However, the estimated interaction effects showed that waiting times post-intervention were only 0.15 times as high as in pre-intervention for MTS1, only 0.49 as high for MTS2, and only 0.68 as high for MTS3. These results can be multiplied on top of the main effects that waiting times for MTS1 were, on average, only a third of the waiting times for MTS5, and waiting times for MTS2 were 0.68 of MTS5 waiting times. The effects of weekends and annual seasons in the model were negligible. On an average day, waiting times increased at around 6 am and from 6 pm to midnight.
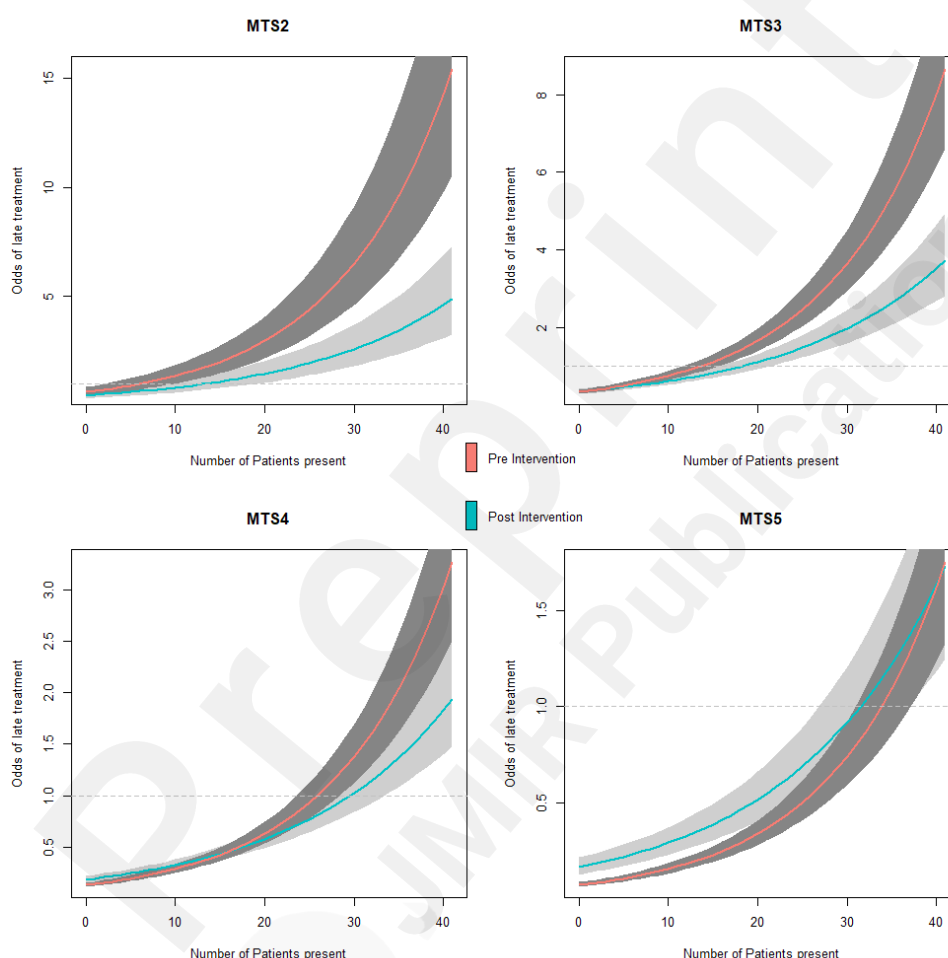

Figure 4: Odds of late treatment by the number of patients present within the ED and study phase for different triage scores and a fixed time (winter at 6 am, on a weekday) with standard normal deviation ($\alpha = 5\%$). The Manchester Triage System (MTS) score determines the time target for timely treatment. Pre-intervention, the time target was displayed to physicians at all times in the EDIS, while it was not post-intervention. The odds were calculated using a generalized additive regression model assuming a logistic regression for delayed treatment. While the odds for late treatment in general increased by 2.32 (CI) when using the new EDIS version (post-intervention) that did not show the time target to physicians, late treatment was considerably less likely when crowding (as indicated by the number of patients waiting) occurred. Severe cases (MTS2, MTS3, MTS4) were less likely to receive late treatment post-intervention. Patients with MTS5 were less likely to be treated on time post-intervention.

We observed some similarities when modeling delayed treatment (model 2, c.f. Supplementary Table 7). The odds of late treatment seemed to increase by 2.32 (CI) post-intervention, but reduced by a factor of 0.32 for MTS2, by 0.44 for MTS3, and by 0.6 for MTS4. These results stand in positive

contrast to the overall odds of delayed treatment of 8.79 for MTS2 compared to MTS5, 4.93 for MTS3, and 1.86 for MTS4. The effects of seasons and weekends are negligible. Similar to positive waiting times, certain hours of the day led to increased odds of delayed treatment – at around 6 am, and from 6 pm to 11 pm.
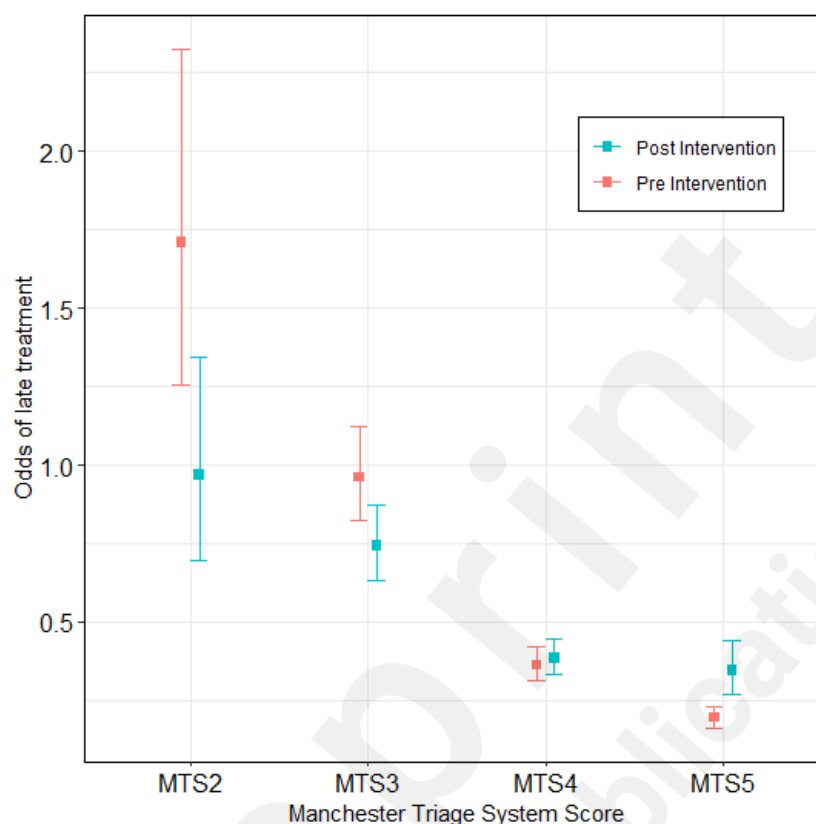

Figure 5: Odds of late treatment by triage score and study phase for a fixed time (winter at 6 am, on a weekday) and patients present (n=13) with standard normal deviation (α = 5%). The time target for timely treatment is determined by the Manchester Triage System (MTS) score and was displayed to physicians at all times only in the old EDIS version (pre-intervention). Odds were calculated using a generalized additive regression model assuming a logistic regression for delayed treatment. The odds of late treatment increased by 2.32 (CI) when using the new EDIS version (post-intervention), which did not show the time target to physicians. However, the odds of late treatment were reduced by a factor of 0.32 for MTS2, 0.44 for MTS3, and 0.6 for MTS4.

Discussion

The introduction of the new software module that did not show the time target for treatment, but instead used a priority list, resulted in prolonged waiting times for patients with lower acuity (MTS4, MTS5) but reduced odds for late treatment of patients with higher acuity (MTS2, MTS3). Similar to what Storm-Versloot [15] observed, patient flow was thus found to be optimized in the second phase of the trial. Critical patients with higher urgency levels received more timely treatment and waited less time, an effect commonly associated with triage systems. When considering all patients, the length of stay and waiting times increased. A longer LOS for all patients eventually leads to crowding and can be used to quantify crowding along with ED occupancy [7]. Indeed, we observed a slightly higher number of patients within the ED at the physician contact stage post-intervention. Paradoxically, the head of the ED and the practicing physicians – professionals who are well aware of crowding and the daily implications of inadequate inpatient capacity – were delighted with the new software, refusing to change back to the old system for further investigation. While these remarks are anecdotal, multivariate regression models confirmed the perception that waiting times for critical patients had reduced. Furthermore, the probability of delayed treatment was also reduced.

Waiting time from triage to treatment was optimized, but the time until triage increased, while overcrowding did not affect the latter. The introduction of the new system led to a more sophisticated triage. Severe cases were treated more effectively, as perceived by the ED staff. Efficient treatment is also reflected in the number of patients sent straight to ED care instead of being triaged [34]; post-intervention, more patients were triaged. We were able to quantify a positive effect of triage with regard to receiving timely treatment when the number of patients waiting increased (c.f. Figure 4). As one might expect, triage has little impact on patient processing when ED occupancy is low and the emergency department is thus not crowded.

The findings support the idea that setting and displaying targets – in this case displaying the time target for the respective MTS – may lead to false incentives. Time constraints may impact the thoroughness of care and the engagement in patient-centered decision-making [35]. We speculate that the knowledge of a time frame leads physicians to a less focused use of resources – particularly for medium urgent cases waiting. Previous work suggests that cues can inadvertently shape clinical priorities and decision-making [27, 28] . This may lead to a phenomenon known as *target behavior*, where the focus of physicians shifts towards meeting set benchmarks rather than optimizing patient care based on clinical needs.

The removal of explicit time targets in our study likely altered the cognitive framework within which physicians operate, redirecting their focus from adhering to arbitrary time constraints to assessing and addressing patient needs more holistically free from the distortions introduced by time pressures. We moved from strict time targets to a patient-centric model post-intervention.

Moreover, the change in the EDIS could have also disrupted habitual response patterns to visible time cues, necessitating a recalibration of treatment prioritization strategies that no longer relied on time targets as a primary directive [36]. This shift could have been further influenced by any briefings or guidance provided to physicians alongside the software change, which might have emphasized a more patient-centric approach to triage and treatment.

One could be tempted to generalize and conclude that waiting limits introduced by policymakers might lead to similar false incentives in much the same way. ED may thus be insufficient as a quality indicator for ED care on its own and instead must be understood as a process metric, especially concerning ED crowding. These conclusions are speculative but similar to what we have previously observed in a larger sample [37].

Limitations

Our study had several limitations, making further research necessary. Post-intervention, data was collected over a shorter time period. However, the number of patients per hour of the day and the total number of patients were comparable. The selection bias should be low; outcomes were measured over time across the whole population of emergency department attendees. Further, our intervention targeted the delivery and organization of services within the ED and was hence on the service level [38]. A controlled evaluation was not possible. A previously proposed prospective study with an on-off study design [39] was not feasible – a controlled evaluation was not possible. Because of this, we cannot assess the effects of minor changes accompanying the introduction of the new EDIS module. However, we assume that these can be neglected, as the changes were either cosmetic or impacted the triage process itself, which does not influence the process times *after* triage. The latter was the case with the changed triage process post-intervention – the only significant non-cosmetic change in this study. The workflow and the processing of patients did not change.

There is evidence, that more formally structured triage leads to an over triage, especially when using the MTS [13, 40–42]. The use of electronic presentation diagrams could thus explain the upcoding in treatment priority that we observed. This fails to explain – especially for non-urgent cases – the fact that the time target for timely treatment was missed in greater numbers, yet patient flow improved. We were unable to assess the influence of raised awareness among ED personnel in general, given the setting of the study. Further work is necessary to address the effects on ED personnel and the

quality of treatment from a provider perspective systematically. Further, future work will have to address patient satisfaction, as the majority of patients had a prolonged ED LOS. We intend to base further work on data from multiple hospitals, which is possible using the infrastructure of the AKTIN Emergency Department Data Registry [32].

Conclusions

The results suggest that it is beneficial not to display time targets when using triage systems, thus confirming the validity of Goodhart's Law. Similar to what others have reported [15, 19, 17], we also showed that the update to the triage system had an unforeseen impact on ED waiting times. Rather than improving the quality of treatment through accelerating processes within the ED, we saw an improvement in patient flow for patients with more severe injuries. Albeit being only anecdotal evidence, the improvement was much appreciated by the attending physicians and the head of the ED. The goal in the ED should always be to work better and, thus, faster. Our work highlights that working better is *not* the same as working faster: working more quickly does not automatically imply better care or results. It is essential to discuss how time is spent instead of focusing on how to save it. Furthermore, our results suggest that using the number of patients present in the ED as an isolated metric for crowding can be misleading.

Acknowledgements

Conflicts of Interest

Guido Becker is employed by Dedalus HealthCare GmbH which manufactures a product related to the subject matter.

Abbreviations

ED: Emergency Department
LOS: Length of Stay
MTS: Manchester Triage System
EDIS: Emergency Department Information System
ESI: Emergency Severity Index
IQR: Inter Quartile Range
OR: Odds Ratio

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Supplementary Files

Figures

Supplementary Figure 2: Effect of hour of day on the generalized additive regression models for positive waiting times between (re)triage and treatment. The covariate hour of day was included with a cyclic P-spline basis. The effects of weekends and annual seasons in the model were negligible. Waiting times increased at around 6 am and from 6 pm to midnight.
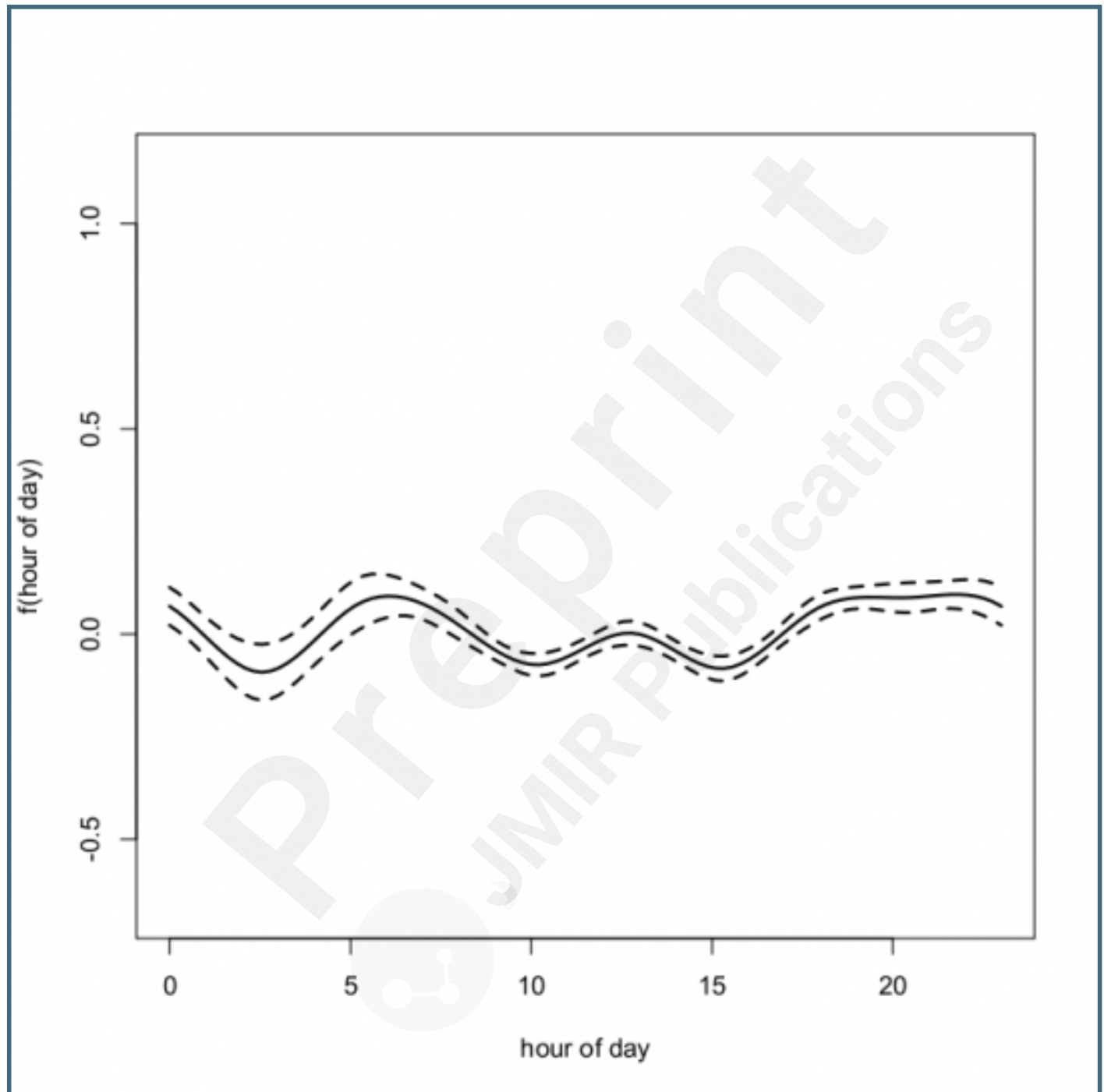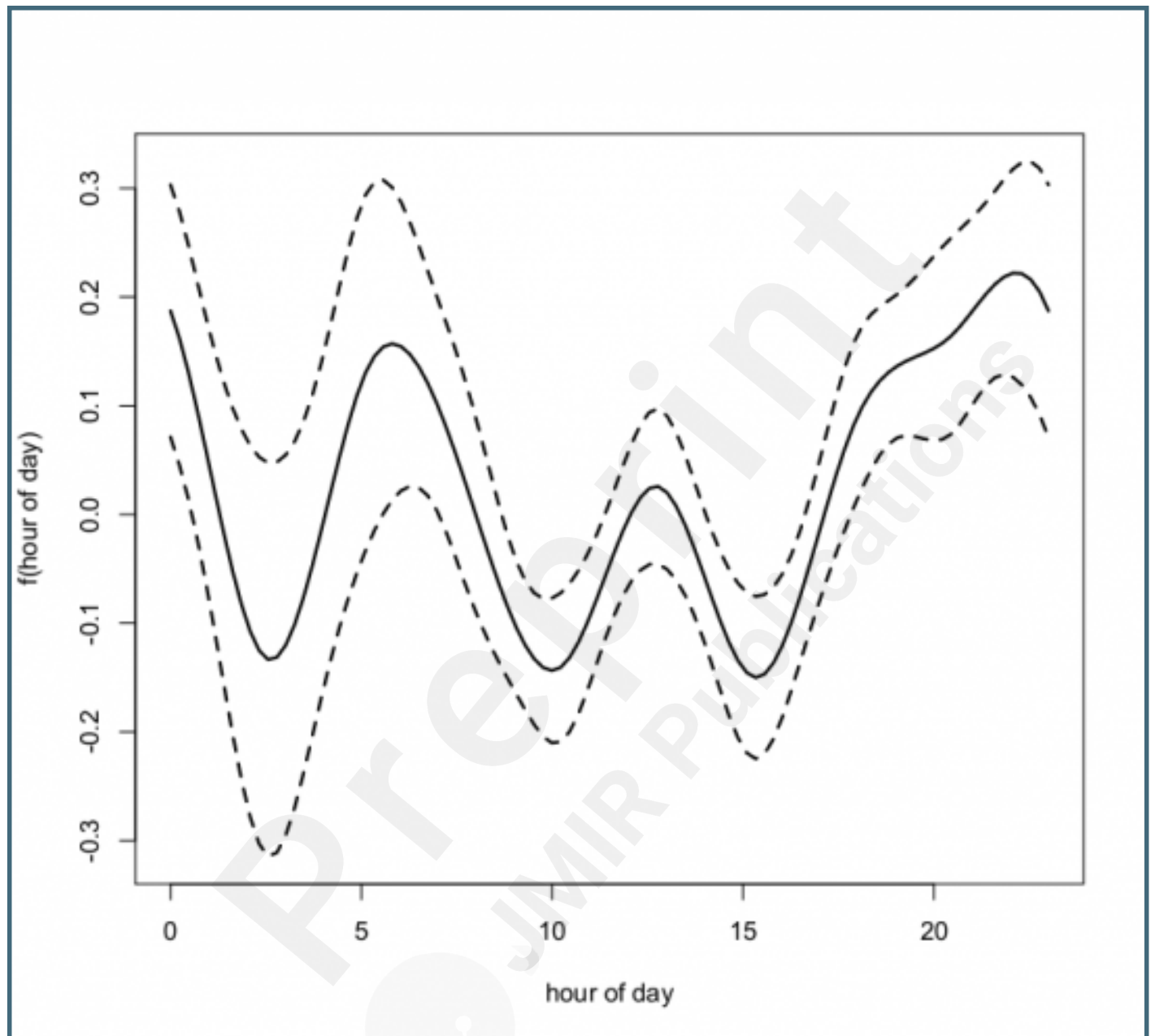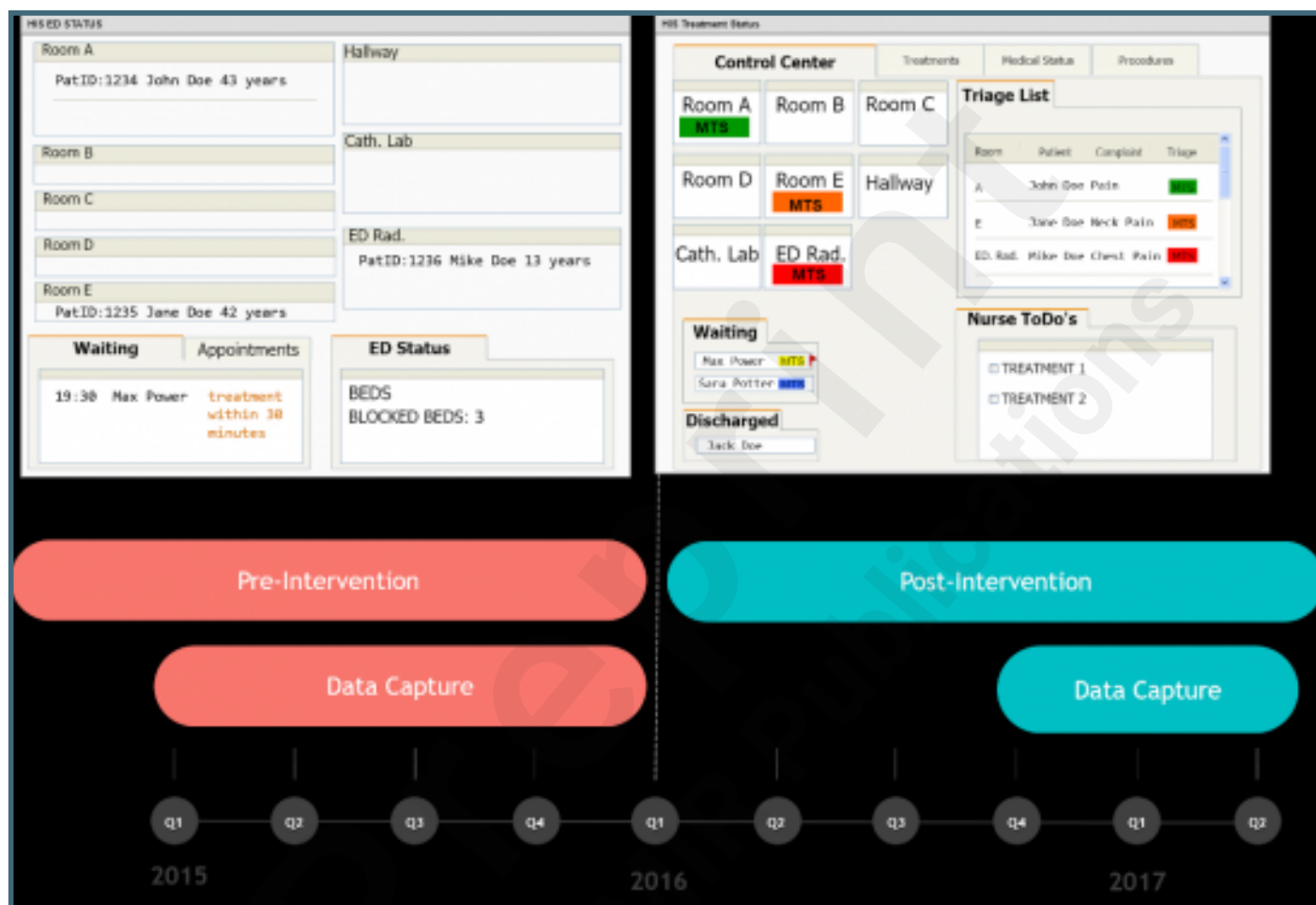
Supplementary Figure 1: Data cleansing and sample sizes. Pre-intervention, treatment time targets provided by the Manchester Triage System score were displayed to emergency department personnel. Post-intervention, time targets were not shown. From 48,822 datasets, a total of 45,186 datasets were analyzed.
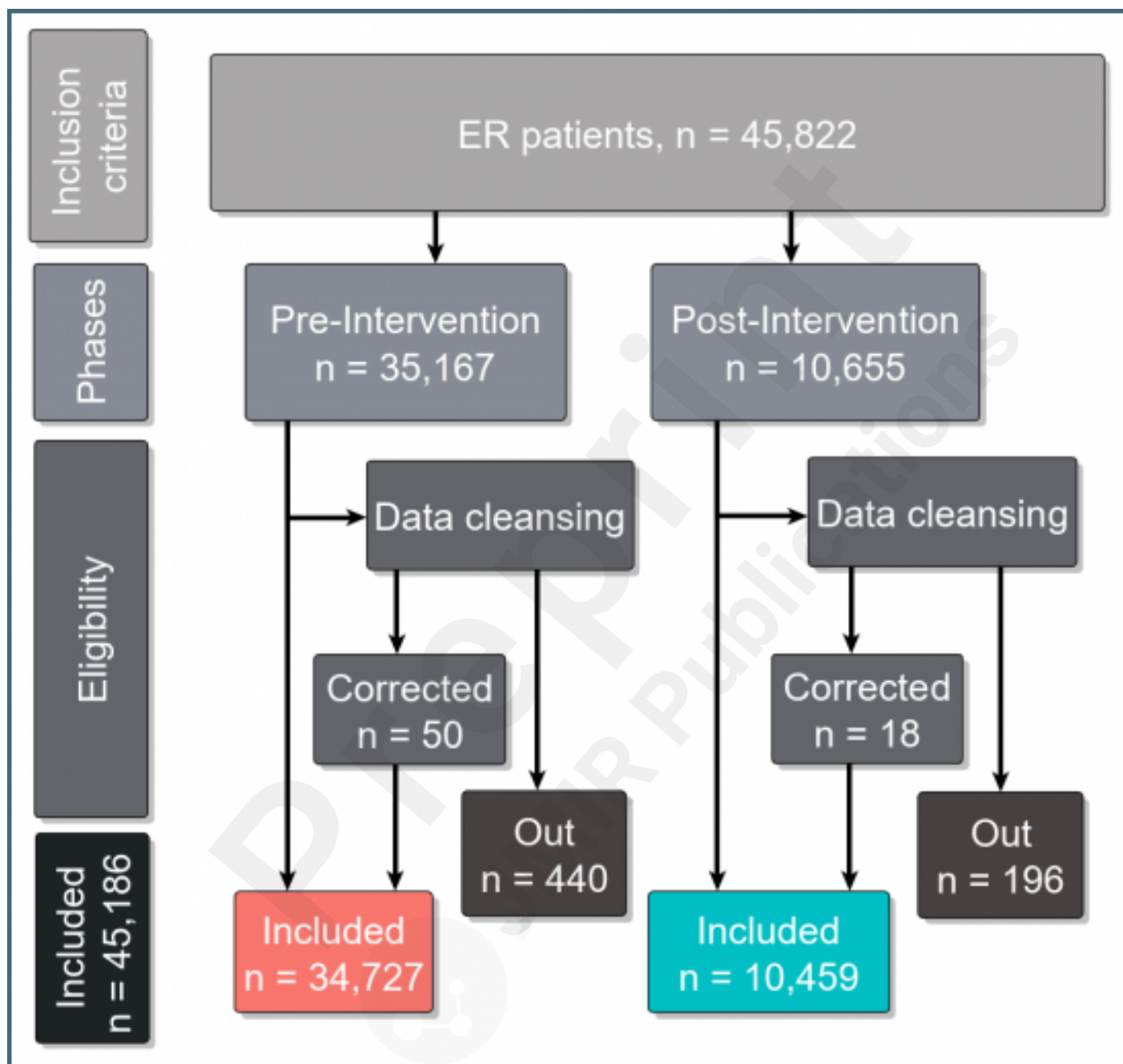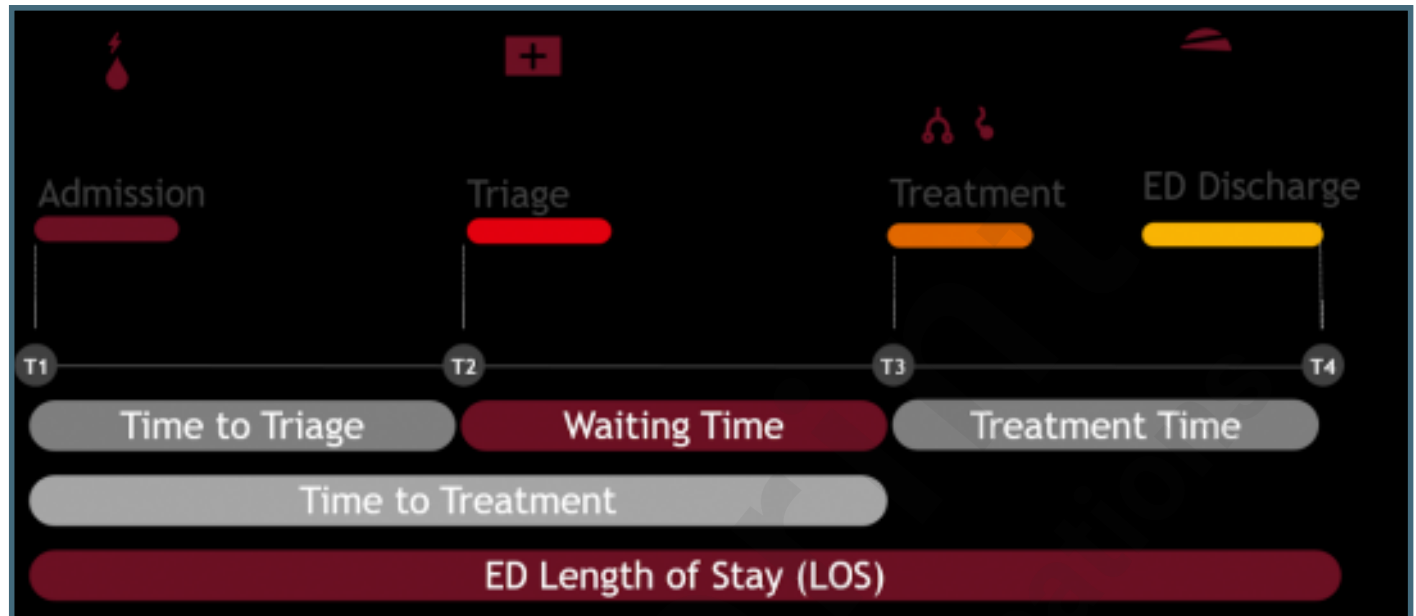
Supplementary Figure 3: Effect of hour of day on the generalized additive regression models for delayed treatment. While the effects of weekends and annual seasons in the model were negligible, odds for delayed treatment increased at around 6 am and from 6 pm to midnight.
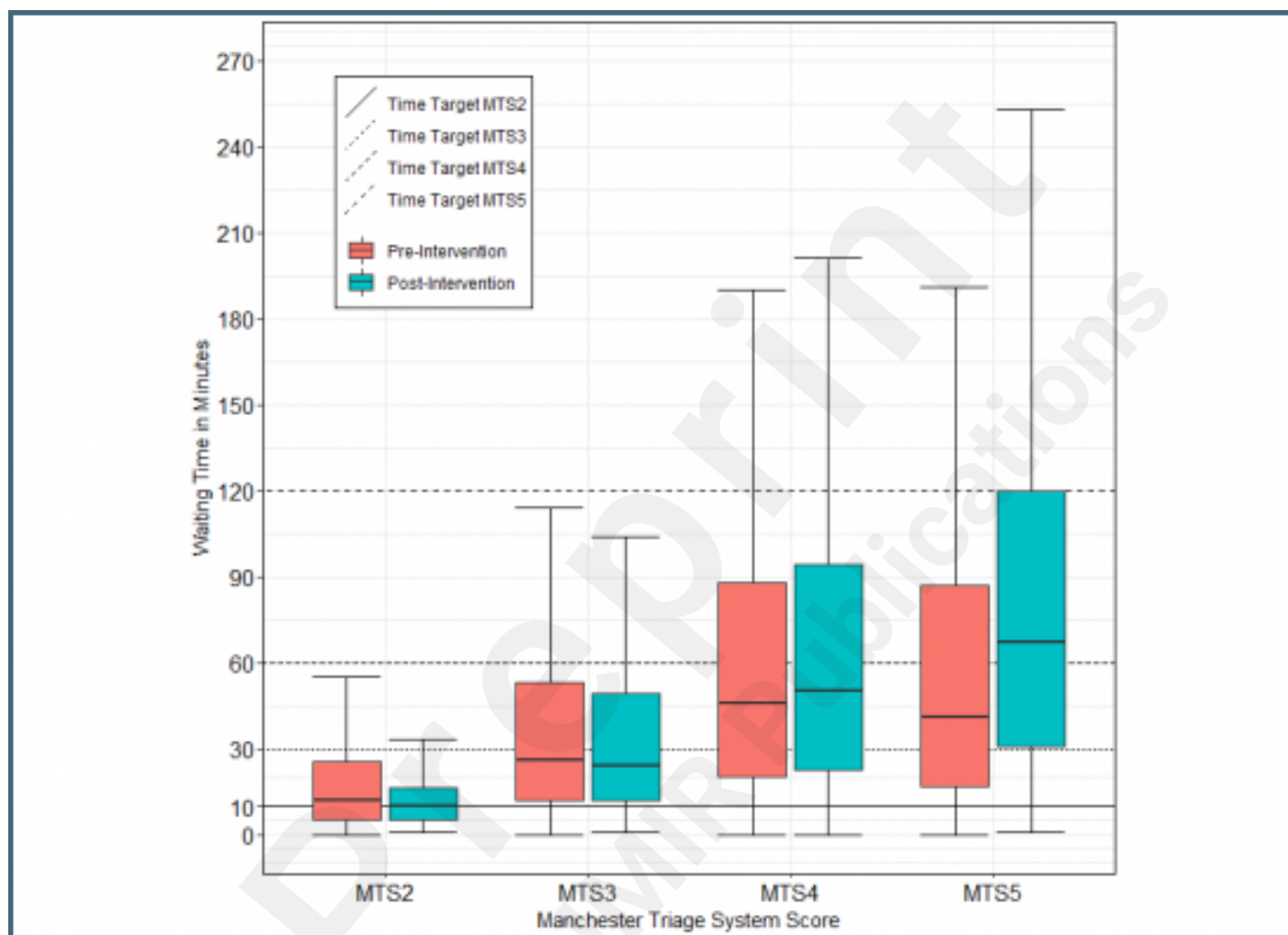
Study design and mock-ups of the emergency department information system (EDIS). In a prospective cross-over study, we evaluated the effect of displaying treatment time targets provided by the Manchester Triage System score to emergency department personnel. Pre-intervention and post-intervention took place before and after the update of an EDIS. The EDIS showed the time target determined by the Manchester Triage System (MTS) pre-intervention (TRIAGE TIME in mock-up). Post-intervention, a priority list (Triage List in mock-up) was displayed instead of a time target. A red flag was displayed next to the color-coded MTS score when the time target was reached.
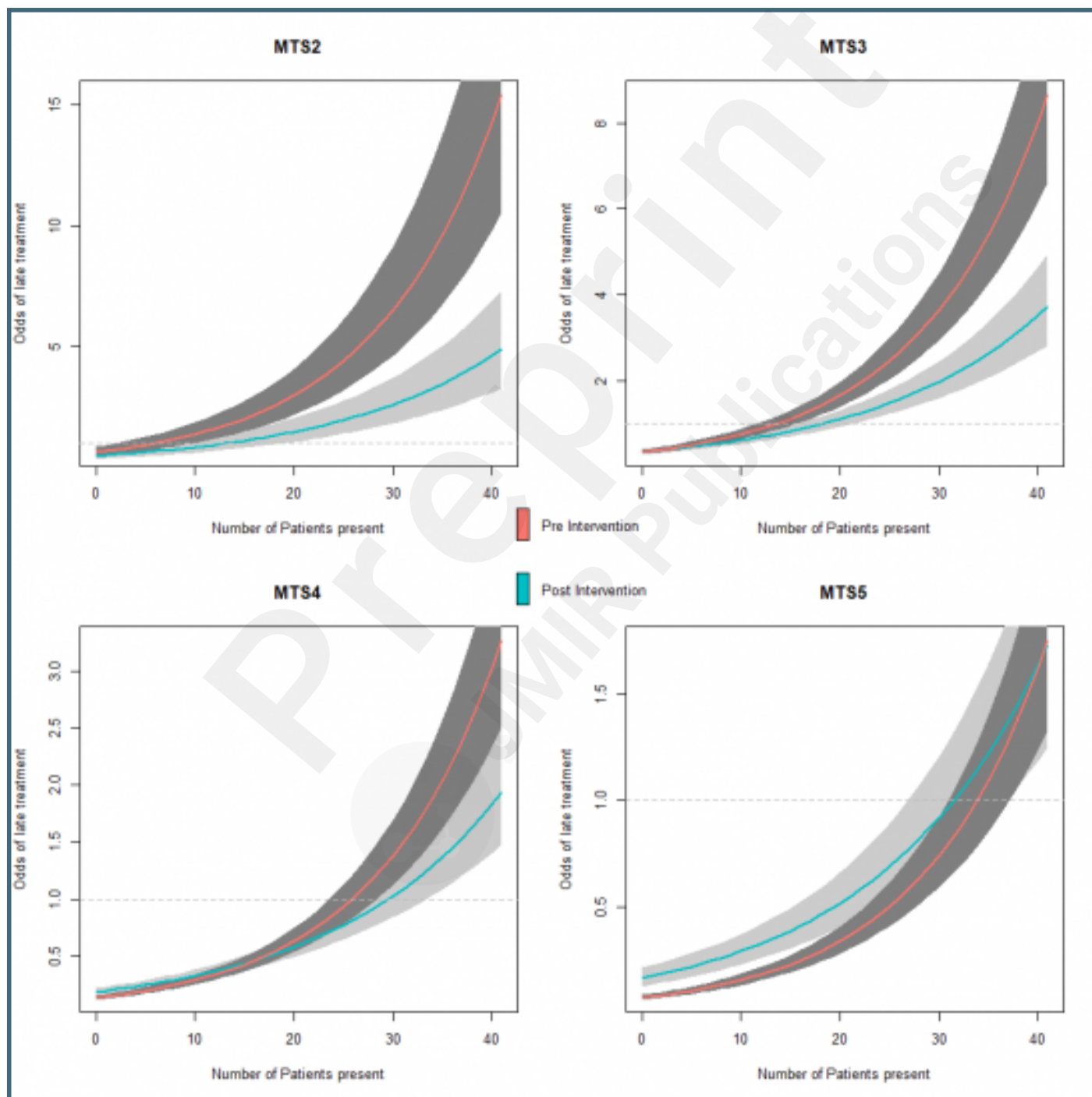
Data collection and variable definition. The evaluation of the intervention was based on routine documentation stemming from an emergency department information system. Timestamps describing internal patient flow were derived from routine medical records. The main target parameters were time to triage (first contact with a triaging nurse), waiting time from triage until treatment by the physician (first contact with the attending physician), and ED length of stay.
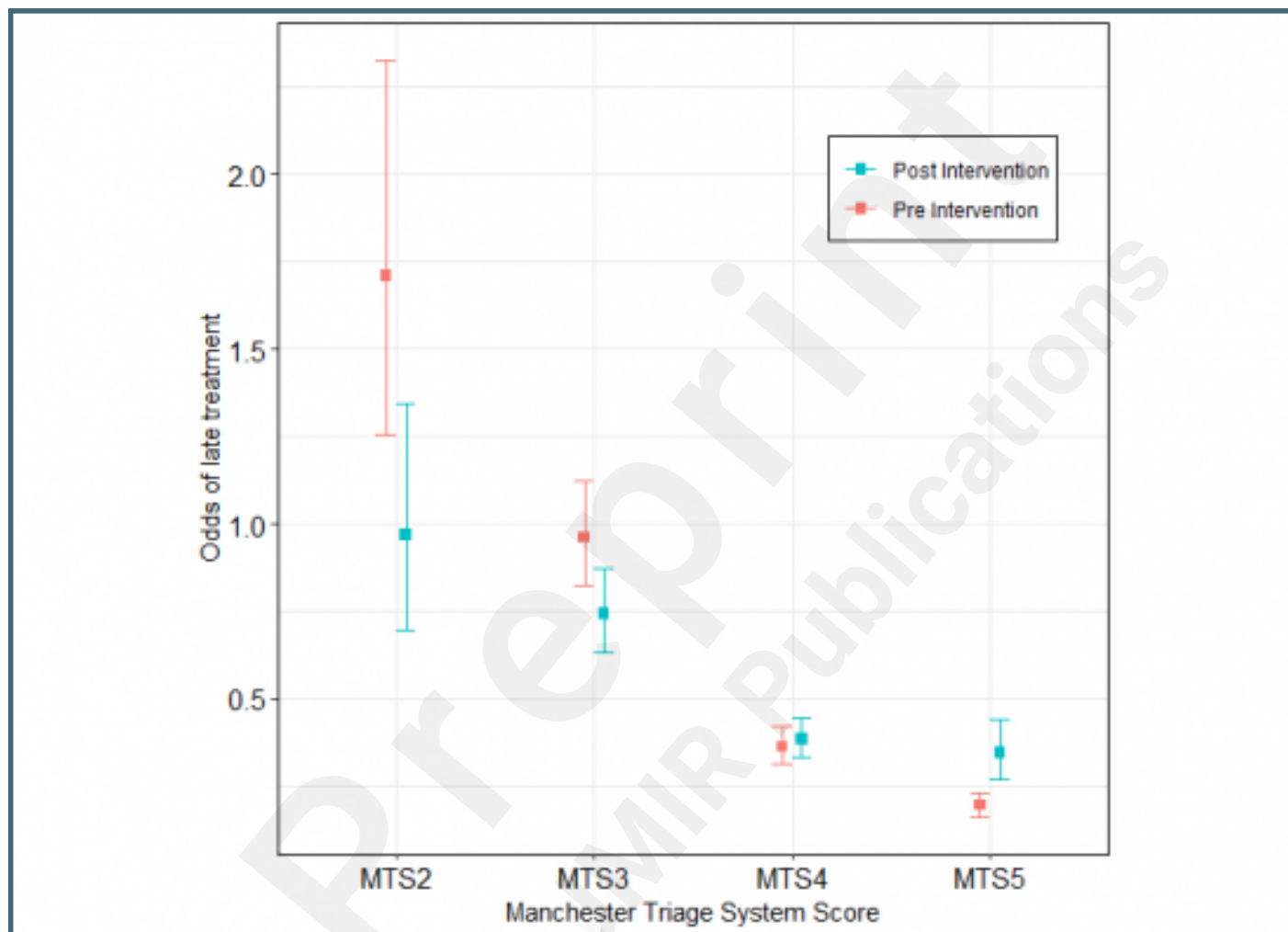
Waiting times from triage to treatment by assigned triage score and study phase. The old EDIS version (pre-intervention, green) displayed the time target determined by the Manchester Triage System (MTS), while the new EDIS version (post-intervention, red) did not. The waiting times from triage until physician contact varied for MTS5 (Pre: 41 min, IQR 17-87; Post: 67 min, IQR 31-121 min), MTS4 (Pre: 46 min, IQR 20-88; Post: 50 min, IQR: 23-95 min), MTS3 (Pre: 26 min, IQR 12-53; Post: 24 min, IQR 11-49 min), MTS2 (Pre: 12 min, IQR 5-26 min; Post: 10 min, IQR 5-16 min) and MTS1(Post: 4 min, IQR 2-14 min).

Odds of late treatment by the number of patients present within the ED and study phase for different triage scores and a fixed time (winter at 6 am, on a weekday) with standard normal deviation (? = 5%). The Manchester Triage System (MTS) score determines the time target for timely treatment. Pre-intervention, the time target was displayed to physicians at all times in the EDIS, while it was not post-intervention. The odds were calculated using a generalized additive regression model assuming a logistic regression for delayed treatment. While the odds for late treatment in general increased by 2.32 (CI) when using the new EDIS version (post-intervention) that did not show the time target to physicians, late treatment was considerably less likely when crowding (as indicated by the number of patients waiting) occurred. Severe cases (MTS2, MTS3, MTS4) were less likely to receive late treatment post-intervention. Patients with MTS5 were less likely to be treated on time post-intervention.

Odds of late treatment by triage score and study phase for a fixed time (winter at 6 am, on a weekday) and patients present (n=13) with standard normal deviation (? = 5%). The time target for timely treatment is determined by the Manchester Triage System (MTS) score and was displayed to physicians at all times only in the old EDIS version (pre-intervention). Odds were calculated using a generalized additive regression model assuming a logistic regression for delayed treatment. The odds of late treatment increased by 2.32 (CI) when using the new EDIS version (post-intervention), which did not show the time target to physicians. However, the odds of late treatment were reduced by a factor of 0.32 for MTS2, 0.44 for MTS3, and 0.6 for MTS4.

Multimedia Appendixes

Supplementary Materials.
URL: http://asset.jmir.pub/assets/ad775bef46a47aafa05a68eb86dfbc7d.docx